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## PRINthead NOZZLE ALIGNMENT IN A PRINTING SYSTEM

### BACKGROUND OF THE INVENTION

In printing systems, such as in inkjet printing systems, one consideration of system design involves the alignment of the printhead nozzles accurately with regard to the scan-axis carriage positioning guide, typically a precision-ground, cylindrical rod or rail. In particular, it is intended that the printhead nozzles be accurately and stably aligned, ultimately, relative to the body of the supporting carriage which rides on this rail, and therefore, accurately and stably also with respect (both translationally and rotationally) to all three of the usual, three, mutually orthogonal reference axes that are associated with the carriage-rail-supporting frame in a printer. Alignment relative to the X axis herein refers specifically to locked alignment relative to the body of the carriage, recognizing that the carriage must move back and forth in the X direction during printing. The carriage is also conventionally permitted a certain amount of rocking about the X axis to deal with printhead print height matters.

The three reference axes -- the X axis which extends (as just indicated) in the printhead scanning direction, the Y axis which extends generally in the direction that print media is advanced through the printzone in the printer, and the upright Z axis -- all typically are carefully respected with regard to proper nozzle alignment so as to achieve, from that perspective, the highest possible printing quality. In the many and various printing systems which have existed in the art to date, this issue of aligning has continued to present challenges -- challenges that relate to economy of manufacture, to maintenance and preparation of close tolerances, to minimizing the number of datuming regions that may be distributed in the carriage/pen/ink-supply interface structure, and to other things.

In relation to known alignment of printhead nozzles with respect to the carriage body in a printer, tolerances exist in what often constitutes an additive-

error stack of tolerance interfaces which results from the presence of plural, successive datuming interfaces that co-exist between the printhead nozzles and the bearings which support the carriage body on the supporting carriage rail. This "tolerance stack" (sometimes referred to as a tolerance loop) is a potential, and often real, contributor to misalignment problems.

#### SUMMARY OF THE INVENTION

The present invention relates to a carriage for use in a printing device, the carriage including a carriage body with a bearing structure configured to support such carriage body for movement along a reference track. The carriage also includes a printhead anchored to the carriage body, and aligned directly relative to the carriage bearing structure.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a top isometric view illustrating portions of an inkjet printer which employs alignment structure and methodology in accordance with one embodiment of the present invention.

Fig. 2 is a larger-scale isolated and fragmentary view of a carriage, a printhead carrier, and an ink-supply system taken generally along the line 2-2 in Fig. 1.

Fig. 3 is a bottom isometric view of the carriage, printhead carrier and ink-supply system of Fig. 2, on about the same scale employed in Fig. 2, and taken generally from the lower side of Fig. 2.

Fig. 4 is a larger-scale, fragmentary schematic diagram illustrating the structure and operation of a plural-axis datuming zone which exists in the mechanical connective interface between the printhead carrier and the body of the carriage in the printer of Fig. 1, including stylized planar representations of several datum surfaces which exist in a datuming socket that is formed on the underside of the carriage.

#### DETAILED DESCRIPTION OF THE INVENTION

Turning attention now to all figures in the drawings, indicated generally at 10 is an inkjet printer which incorporates one embodiment of the present invention, and which is based upon one manner of practicing the methodology of the present invention. It is to be appreciated that although printer 10 takes the

form of a stand-alone inkjet printer, the present embodiment of the invention may be employed in a variety of printing devices, including copiers, facsimile machines, etc.

Included in printer 10, and indicated just fragmentarily in dashed lines at 12 in Fig. 1, is a frame with respect to which there may be associated mutually orthogonally-related reference axes, referred to herein as a foundation set of axes. Such reference axes are pictured in relation to one another in a graphical presentation at X, Y and Z toward the left side of Fig. 1.

As indicated, in printer 10, the X axis extends generally in the printhead scanning direction, which is indicated by double-ended arrow 14, the Y axis extends generally along a line which is in the direction of paper, or print-media, advance through the printzone 16, and the Z axis extends generally vertically. These three reference axes typically directly relate to translational positioning, alignment or adjustment of structure associated with printer 10.

Associated with each of these three translational axes is a rotation which relates to rotational positioning, alignment or adjustment that may also be accomplished by the apparatus and methodology of the present embodiment of the invention. With respect to axis X, this rotational characteristic is shown at  $\theta_x$ , with respect to the Y axis, the characteristic is shown at  $\theta_y$ , and with respect to the Z axis, at  $\theta_z$ .

Further included in printer 10 is a carriage, or carriage means 18, having a carriage body 18a which is mounted, through appropriate spaced bearing structures, for riding back and forth generally in the reversible directions indicated by previously-mentioned double-ended arrow 14. Specifically, carriage 12 may be mounted for such movement on and along a reference track such as elongate carriage rail 20. As will be appreciated by those skilled in the art, opposite ends of carriage rail 20 may be suitably anchored, and thereby datumed, to frame 12. Such datuming for the carriage rail locks the rail in place relative to all three of the reference axes in printer 10, and also with respect to all three of the rotational motions that are associated with those three axes. The long axis of carriage rail 20 is shown at 20a. This axis parallels the X reference axis in Fig. 1.

Bearing structure which directly supports the carriage body on rail 20 may either be separate bearing structure which is suitably interposed these two structures, or it may be structure which is formed integrally in and with carriage body 18a. This bearing structure generally resides in the locations pointed to by arrows 22 in Figs. 1, 2 and 3. A variety of suitable bearing structures may be used such as that shown in U.S. Patent No 5,366,305 to Christianson, which is commonly owned by the current assignee, Hewlett-Packard Company of Palo Alto, California.

Focusing attention especially on Figs. 2 and 4, and stating first a bit more about the nature of Fig. 4, Fig. 4 isolates certain surface structure in the interface region which exists between a carriage body and a printhead carrier. To do this, it utilizes several fragmentary imaginary planes which represent orthogonally-intersecting surfaces in a socket (shortly to be described) on the underside of the carriage. Also employed in Fig. 4 are fragments of certain physical, three-dimensional structure present in the carriage body and in the nozzle plate.

Thus, included in printer 10, and securely anchored and datumed on and with respect to carriage body 18a are a printhead carrier, or printhead carrier means 24, and an ink-supply system, or ink-supply means 26. A printhead 28 also is included, the printhead having a plurality of ink-dispensing nozzles configured to print on media passing through printzone 16. The printhead is mounted on the printhead carrier, but aligned relative the bearing structure as will be described further below. Ink supply system 26 is suitably fluidly connected to ink-dispensing nozzles of the printhead via printhead carrier 24. The printhead carrier thus will be seen to operate as an ink manifold between ink supply system 26 and the ink dispensing nozzles of printhead 28.

Printhead carrier 24 and ink-supply system 26 may be anchored in place through anchoring structure, such as bolts 29, which are also referred to herein as anchoring means. Bolts 29 typically extend through what is referred to as a mounting structure portion of carriage body 18a to form what is referred to herein as a sandwich structure, or sandwich means. Once such assembly is completed, typically during manufacture of the carriage, printhead 28 may be mounted on printhead carrier 24, and aligned directly relative to the carriage bearing structure.

This alignment may be accomplished by any of a variety of precision alignment methods, including mechanical fixture systems, vision systems, laser systems, etc. For a vision alignment, it is to be noted that features for alignment may include the ink-dispensing nozzles of the printhead and the run axis of the bearing structure (which coincides, in the drawings, with axis 20a).

Typically, one important alignment between the carriage bearings and the printhead is  $\theta_z$  alignment of the nozzles relative to the run axis of the bearings (the X axis). This alignment may significantly affect print quality due to potential skewing of vertical lines. Another issue addressed by proper  $\theta_z$  alignment relates to maintaining column length of printhead nozzles. It will be appreciated that as a column of nozzles rotates, the length of the column decreases. Accordingly, from print swath to print swath, the tops and bottoms of the swaths may not mate along the Y axis, potentially causing a noticeable banding effect. Alignment of the printhead relative to the X axis, Y axis,  $\theta_x$ ,  $\theta_y$ , and Z axis also may be accomplished. As will be appreciated, where the printhead is aligned directly to the carriage bearing structure, it may not be necessary to make further measurement alignment adjustments to the printhead upon placement of the carriage on the carriage rail.

Turning now to a discussion of datuming of the printhead carrier, it will be appreciated that the body of printhead carrier 24 may include a rectilinear portion 24a (see particularly Fig. 2), also referred to herein as a plural-axis-datuming datum-reference structure, and which functions as a docking structure, or docking means, that is received and plural-axially-datumed, in a rectilinear socket, or socket means 18b. Socket 18b, it will be noted, may be formed herein on the underside of carriage body 18a. Socket 18b, also called a plural-axis-datuming datum-reception site, along with docking structure 24a of the nozzle plate, collectively define a datuming zone. This datuming zone is referred to specifically as a single-region, plural-axis-datuming zone, which functions, according to one embodiment of the invention, as the single, datuming and connective interface between the carriage body and the printhead carrier. As will be explained, this datuming zone may be defined by pairs of contacting confronting surfaces, surface structure, or surface means, which function(s) as a collection of datum

surfaces in the printhead carrier and socket. It will be appreciated that, for purposes of clarity, the term datuming is used herein to refer to alignment of the printhead carrier relative to the carriage because of the associated physical structure employed, but that such reference is not intended to be limiting in that sense.

In general terms, docking portion 24a of the printhead carrier has a rectilinear configuration defined by planar, orthogonally-related surfaces collectively occupying all respective pairs of intersecting reference axes X, Y and Z in the printer. In the printhead carrier, these orthogonally-intersecting surfaces may include (1) a pair of lateral-side surfaces which are spaced apart and which parallel one another, and one of which is shown at 24b, (2) a front surface 24c, (3) a rear surface 24d, and (4) an upper surface 24e. Surfaces 24b lie in spaced vertical parallel planes, each of which contains, effectively, reference axes Y and Z. Surfaces 24c, 24d lie in spaced parallel vertical planes, each of which contains, effectively, intersecting reference axes X and Z. With the printhead carrier mounted and datumed as shown on the body in the carriage, the nozzles in the subsequently-aligned printhead face downwardly toward printzone 16, as indicated generally at 30 in Figs. 2 and 3.

The portion 18c of carriage body 18a which is sandwiched between the printhead carrier and the ink-supply system is also referred to herein as a mounting reception structural portion of the carriage body. This portion is generally planar, and typically includes an upper surface 18d and a lower surface 18e. Surface 18e typically faces downwardly toward the underside of the carriage body. Surfaces 18d, 18e each typically lie in a plane which contains reference axes X and Y. Surface 18e typically forms the upper, downwardly-facing, orthogonally-related datum surface in previously-mentioned socket 18b. Joining with downwardly-facing surface 18e in the carriage body to define datuming socket 18b are an upright front surface 18f, an upright rear surface 18g, and two laterally-spaced side surfaces 18h, 18i. All of the surfaces which make up the datuming socket on the underside of the carriage body may be formed with precision at the time that the carriage body is manufactured, and are completely integral with the carriage body.

With regard to ink-supply system 26, what is pictured generally in outline form in Figs. 1 and 2 for this ink-supply system is what is referred to as an ink management hull. This hull may be suitably seated in appropriate receiving space provided for it within carriage body 18a. The undersurface portion, or at least a part of that undersurface portion, of the ink-supply system rests, and is supported, on carriage body surface 18d. It may be held in place, along with the printhead carrier, in the structure now being described by previously-mentioned, laterally-spaced bolts 29 which may be disposed on upright axes, shown by dash-dot lines at 29a in Figs. 1-4, inclusive. The shanks in these two bolts may extend through suitable accommodating bores, such as bore 18j in carriage body portion 18c (see particularly the single bore 18j shown in Fig. 4). Bolts 29 may be tightened to draw the printhead carrier and the ink-supply system tightly into clamping engagement on opposite sides of mounting portion 18c of carriage body 18a, the ink-supply system effectively acting as a nut for receipt of bolts 29. This tightly-clamped arrangement creates the sandwich structure mentioned earlier, locks the ink-supply system into reliable, positional configurational relative to the printhead carrier. This datumed relationship addresses both translational and rotational datuming of the printhead carrier relative to reference axes X, Y, Z.

As indicated above, with the printhead carrier in place, printhead 28 may be mounted on the printhead carrier during manufacture, and datumed directly relative to the carriage bearing structure at that time. This, in turn, may provide reliable positioning of the printhead relative to media subsequently passing through the printzone. This effectively further reduces the tolerance stack of the printhead. Furthermore, because the printhead carrier is datumed separately a level of compatibility may be provided so as to provide for use of the proposed arrangement amongst a variety of differing printing devices.

Through appropriate pre-alignment and adjustment at the time of manufacturing of the carriage, the above-described datumed relationship may be established, and this established relationship may create plural-axis, accurate and configurationally-stable datuming between the printhead carrier and the carriage. Correspondingly, proper alignment may be achieved between the printhead and the carriage bearing structure upon attachment of the printhead to

the printhead carrier, also at the time of manufacturing of the carriage. Accordingly, and through appropriate datuming which exists in the regions of previously-mentioned bearing structures 22, the printhead carrier is furnished with a single-region, plural-axis datuming interface to the reference axes (X, Y, Z) associated with frame 12. This datumed condition for the printhead carrier is a condition which effectively datums the printhead carrier not only translationally with respect to the three reference axes, but also rotationally with respect to the rotational considerations illustrated in several of the figures at  $\theta_x$ ,  $\theta_y$  and  $\theta_z$ . This statement about datuming, of course, recognizes that rail 20 allows for X-direction motion of the carriage during printing, as well as a certain amount of  $\theta_x$ -rotation to deal with conventional printhead print-height considerations. In Fig. 4, associated with rail axis 20, two (Y and Z) of the three reference axes are shown, along with  $\theta_y$  and  $\theta_z$ . This has been done to point out that rail 20 furnishes only Y and Z datuming of carriage 18.

There thus results a unified, tightly-datumed structure which addresses many of the concerns expressed earlier regarding appropriate, reliable, multi-axis datuming and alignment, without coexistence of the tolerance-stack issue mentioned earlier. The provision of a multi-axial datuming socket on the underside of the carriage body is considered to be a good way of implementing both the structure and the method of the present invention, but we recognize that other datuming and alignment locations for multi-axial, six-degree-of-motion-datuming and alignment could be selected to suit different applications if so desired. It would be possible, for example, to form an integral carriage and printhead carrier, and to align the printhead relative to structure bearings at the time of manufacture, but such arrangement may reduce adaptability of the structure.

By clamping the printhead carrier along with the ink-supply system in an arrangement which sandwiches an intermediate portion of the carriage body, a very simple structure which can provide very simple and accurate datuming that will hold positional stability over a lifetime of printer use is provided. Such co-anchoring of the printhead carrier and the ink-supply system also tightly and reliably pre-positions these two, thus stabilizing the effectiveness and continuities



of fluid paths which are provided for supplying ink to the nozzles in the printhead carrier from the ink-supply system. Mounting the printhead on the printhead carrier at the time of manufacture allows datuming of the printhead relative to the bearing structure, so as to reduce the tolerance stack.

5 The methodology which involves configurationally and stably aligning printhead nozzles in a printing device thus may be seen to include aligning the printhead relative to the bearing structure of the carriage, typically at the time of manufacture of the carriage. In the present embodiment, this is illustrated in the context of a carriage having a printhead carrier which is datumed with respect to  
10 the carriage of a printer, and wherein the carriage includes a datuming socket adapted to receive a docking portion of such a printhead carrier. This datuming may be accomplished by the steps of: (a) selecting surfaces in that socket to be datuming surfaces; (b) selecting surfaces in the docking portion of the printhead carrier also to be datuming surfaces; (c) orienting those datuming surfaces  
15 whereby confronting contact occurs between adjacent pairs of these surfaces which is effective to produce plural-axis datuming of the printhead carrier relative to the carriage; and (d) securely anchoring the printhead carrier to the carriage with the mentioned datuming surfaces contacting one another in a manner producing the mentioned plural-axis datuming. The method also includes  
20 effectively anchoring the printhead carrier to an ink-supply system that supplies ink to nozzles in the printhead carrier in such a fashion as to create a sandwich structure, with a portion of the carriage sandwiched tightly and securely between the printhead carrier and the ink-supply system. Thereafter, the printhead may be mounted on the printhead carrier in a secure manner, the printhead being  
25 aligned directly relative to the bearing structure.

In conclusion, an ink-dispensing printer, the stable alignment of ink-dispensing nozzles rotationally and translationally relative to the usual three X, Y and Z reference axes associated with the frame in the printer is a consideration that relates significantly to printing quality. The illustrated system proposes the  
30 implementation and use of structure and methodology which address this alignment consideration by providing for alignment of the printhead directly relative to the carriage bearing structure at the time of carriage manufacture

without giving up on adaptability achieved through the use of a removable, replaceable and interchangeable printhead carrier. The printhead carrier is datumed by creating and employing a single-region, plural-axis datuming interface at a location which is intermediate a printhead carrier and the carriage  
5 body. In the datuming setting proposed, the printhead carrier is anchored to an associated ink-supply system which is also carried on the carriage. Anchoring takes place through structure that unites the printhead carrier and the ink-supply system in a clamping arrangement on opposite sides of a portion of the carriage body, thus to create a tight, stable sandwich assembly which includes the  
10 printhead carrier, the ink-supply system, and the body of the carriage. The printhead then may be mounted on the printhead carrier, and datumed directly relative to the carriage bearing structure.

While the invention has been particularly shown and described with reference to the foregoing preferred embodiments, those skilled in the art will understand that many variations may be made therein without departing from the spirit and scope of the invention as defined in the following claims. The description of the invention should be understood to include all novel and non-obvious combinations of elements described herein, and claims may be presented in this or a later application to any novel and non-obvious combination  
15 of these elements. Where the claims recite "a" or "a first" element or the equivalent thereof, such claims should be understood to include incorporation of one or more such elements, neither requiring nor excluding two or more such elements.